Granular Metamaterials and Periodic Structures for Protection from High-Velocity Impacts

Completed Technology Project (2013 - 2017)

Project Introduction

The unique dynamics of stress waves travelling through chains of spheres has been extensively studied in the elastic-regime and has been shown to create cohesive pulses called solitons that travel through the chains at a rate that depends on the amplitude of the pulse. Because of their demonstrated ability to effectively disperse small shocks, trap energy, reflect and redirect pulses, we are now exploring the applications of solitons in granular crystals to create materials which can effectively survive extremely high-velocity impacts with strain rates on the order of 10^5 -10^7 /sec. The goal of this research is to design and create 3D metamaterials for shock dissipation, leveraging the non-linear dynamics of microstructured materials. This research could lead to multifunctional materials of interest to NASA with improved impact protection as well as radiation resistance and greater thermal control. Research on the dynamics of granular crystals of spheres at very high strain rates and pressures is a new field. Therefore, we don’t know how effects such as plasticity and the strain-rate dependence of the materials, previously considered negligible, will change the properties of stress waves through our materials. We can simulate the physics using finite element methods and lumped mass models of the system and we can perform experiments at various strain-rates using a Hopkinson bar and powder gun. We plan on using this improved understanding of the dynamics of chains of spheres as a starting point on which to grow a catalog of non-linear materials which will allow for the design of metamaterials with tuned and diverse properties for applications in micrometeoroid and orbital debris protection as well as many defense applications. In order to expand the capabilities of our materials, we are also interested in exploring the dynamics of materials that exhibit structural instabilities such as buckling and snap-through. Because materials with instabilities can achieve stiffness and damping properties not typically observed in stable materials, incorporating them into the our granular crystals creates novel ways of controlling energy propagation through structures.

Anticipated Benefits

This research could lead to multifunctional materials of interest to NASA with improved impact protection as well as radiation resistance and greater thermal control.

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Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

Space Technology Research Grants

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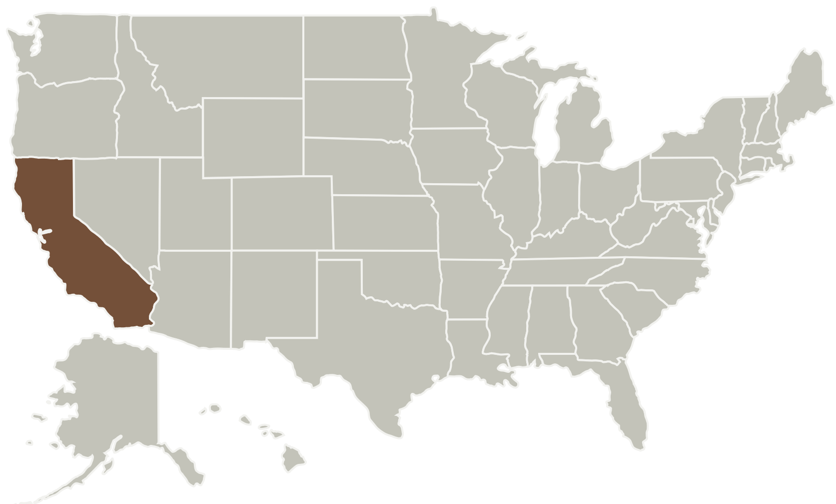
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
California Institute of Technology(CalTech)	Supporting Organization	Academia	Pasadena, California

Primary U.S. Work Locations
California

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Project Management

Program Director:
Claudia M Meyer

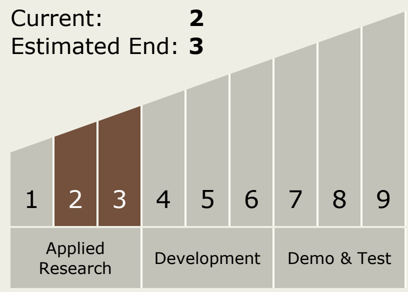
Program Manager:
Hung D Nguyen

Principal Investigator:
Guruswami Ravichandran

Co-Investigator:
Hayden A Burgoyne

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
  └─ TX12.1 Materials
    └─ TX12.1.7 Special Materials